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SOME EFFECTS OF REYNOLDS AND MACH NUMBERS ON

THE LIFT OF AN NACA 0012 RECTANGULAR WING IN

THE NACA 19-FOOT PRESSURE TUNNEL

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SOME EFFECTS OF REYNOLDS AND MACH NUMBERS ON

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SUMMARY

A short investigation was made in the NACA 19-foot
pressure tunnel to determine the aerodynamic character-
istics of a rectangular wing model constructed to NACA
0012 airfoil sections. The tests were run with the air
in the tunnel at two different pressures: atmospheric
(14.7 lb/sq in. abs.) and 35 pounds per square inch abso-
lute. The Reynolds number ranged from 1,070,000 to
5,250,000 for the tests at atmospheric pressure and from
1,960,000 to 8,240,000 for the tests at a pressure of 35
pounds per square inch absolute. The results indicate a
marked compressibility effect on the lift coefficients,
particularly the maximum lift coefficients, which increase
up to a velocity of approximately 150 miles per hour (a
Mach number of 0.19) and then decrease rapidly. The re-
sults also indicate that, in wind-tunnel testing to de-
termine maximum lift coefficients, compressibility effects
may be avoided by limiting the tunnel air-stream test
velocity to about 125 miles per hour (a Mach number of
0.17)

INTRODUCTION

During the calibration of the NACA 29-foot pressure
tunnel a few years ago, tests were made with a rectangular
metal wing constructed to NACA 0012 airfoil sections. The
results of these tests, which are reported herein and
which have been reported in part as unpublished data of
the NACA 19-foot pressure tunnel in references 1 and 2,
showed compressibility effects on the lift coefficients
that are believed to be of considerable importance in wind-
tunnel testing technique as well as in connection with

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certain phenomena observed in flight. Inasmuch as the
information provided by the present tests is somewhat
scanty, further tests are contemplated when the pressure
of the present military testing program is relieved.

TESTS AND RESULTS

Figure 1 gives the details of the model. *The* test
setup of the model mounted in the tunnel *is* shown in fig-
ure %. Force tests were made over an angle-of-attack
range from below zero lift through the stall with the air
in the tunnel at two pressures, atmospheric (14.7 lb/sq in.
abs.) and 35 pounds per square inch absolute. Tho tests
were made at values of dynamic pressure from 10 *to* 200
pounds per square foot, which gave test Reynolds numbers
from 1,070,000 to 5,250,000 at atmospheric pressure and
from 1,960,000 to 8,240,000 for *35* pounds per square inch
pressure.

Tests were made to determine the effects of support
tare and interference, and corrections for these effects
were made to tne coefficients presented herein. The
angles of attack are corrected for jet-boundary effects.

The variation of the lift coefficient C_L with angle
of attack a is given in figures 3 and 4 for the tests
at the different Reynolds numbers and the two tunnel air-
pressure conditions. Examination of these curves reveals
some variation of lift-curve slope with Reynolds number.
Correcting the slopes to infinite aspect ratio a_0 and
plotting a_0 against test Reynolds number (fig. 5) gives
a separate curve for each of the two tunnel air pressures.
When a_0 is plotted against Mach number, however, the
two curves show fair agreement in that the breaks occur
at approximately the same Mach number (fig. 5).

In figure 6, the maximum lift coefficient $C_{L_{max}}$ is
plotted against test Reynolds number for the two pressure
conditions. *For* atmospheric pressure, the value of $C_{L_{max}}$
increases up to a velocity of approximately 150 miles per
hour after which it decreases at a rapid rate for the re-
maining portion of the range investigated. Increasing
the pressure of the air in the tunnel extends the curve
obtained at atmospheric pressure to higher values of $C_{L_{max}}$

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and to higher values of critical Reynolds number as indi-
cate&by the dashed-line curve. The critical Reynolds
number in this case also corresponds to a velocity of
approximately 150 miles pes hour. When these same values
of $c_{L_{max}}$ are plotted against Mach number as in figure 7,
however, both curves show the peak at approximately the
same Mach number (0.19) indicating that the breakdown of
the flow is a compressibility effect. A few pressure
measurements over the nose of the wing indicate this to be
the case. Further detailed pressure measurements are
desirable. It should bo remembered, however, that both
Reynolds and Mach number effects are combined in the results
of figures 6 and 7 and *that* the variation of $c_{L_{max}}$ is due
to a combination of these two effects. On the other hand,
compressibility effects are quite small for Mach number8 up
to 0.17 and variations of $c_{L_{max}}$ below this value therefore
are essentially true Reynolds number effects. In refer-.
ence 2, it has been shown Pi-om two-dimensional pressure-
distribution tests of airfoils of the NACA 16-series that
the curve of $c_{L_{max}}$ against Mach number starts upward
again. at higher Mach numbers with pronounced increases of
maximum lift coefficient being obtained. Unfortunately, it
was not possible in the present tests to obtain the high Mach
number necessary to show this effect. Further Force tests
at high Mach numbers appear to be very desirable.

The results of the present investigation of the NACA
0012 wing indicate that tests for the determination of
maximum lift coefficient should be made at the Reynolds
and Mach numbers corresponding to those existing for the
conditions at which the data will bo used. Unfortunately,
duplication of anticipated conditions of size, altitude,
and velocity would be required because the proper Reynolds
and Mach numbers can be simultaneously obtained in no
other way. Inasmuch as the majority of wind tunnels are
dependent upon velocity changes far variation of Mach num-
ber, the effects of compressibility and Reynolds number
thus obtained cannot bo separated; consequently, tho Mach
number effects at $c_{L_{max}}$ may predominate at much lower
than ths desired Reynolds number and the data will be mis-
leading. Because the majority. of maximum-lift data are
applied to the landing and stalling conditions of airplanes
in which the velocities are usually less that 125 miles
per hour, the compressibility effects are small. For this

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reason, it would appear desirable in most cases to make
the wind-tunnel tests for maximum lift coefficient at
values of Mach number sufficiently low that compressibil-
ity effects will be negligible. The present tests indi-
cate that an air-stream velocity of approximately 125
miles per hour (a Mach number of 0.17) would be the upper
limit for airfoils with pressure distributions similar to
that of the NACA 0012 section. For flight attitudes that
require maximum lift at high Mach and Reynolds numbers,
such as would be obtained In high-speed turns, however,
both the proper Mach and Reynolds numbers should be
duplicated.

CONCLUSIONS
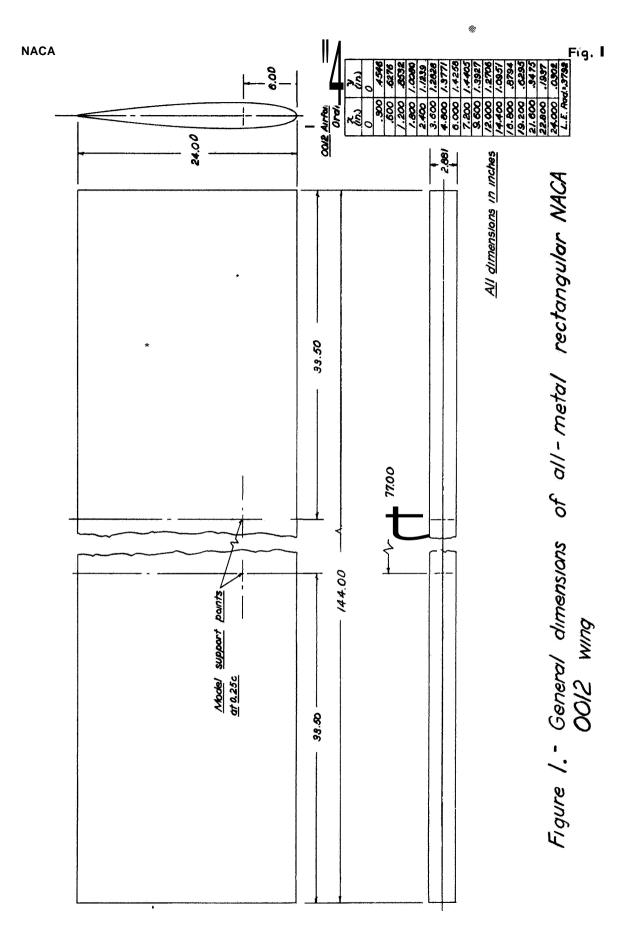
From the tests of an NACA 0012 rectangular wing in
the NACA 19-foot pressure tunnel herein reported, the
following conclusions may be drawn:

1. Compressibility effects produce pronounced changes
in the value of the maximum Lift coefficient for Mach
numbers exceeding approximately 0.17. Below this value,
Reynolds number effects apparently predominate,

2. Determination of the maximum lift coefficient by
wind-tunnel tests must therefore be done with due regard
for the flight condition to which the results will be
applied.

Langley Memorial Aeronautical Laboratory,
    National Advisory Committee for Aeronautics,
        Langley Field, Va.

REFERENCES

1. Stack, John: Compressibility Effects in Aeronautical
    Engineering. NACA A.C.R., Aug. 1941.

2, Stack, John, Fedziuk, Henry A., and Cleary, Harold E.:
    Preliminary Investigation of the Effect of Compress-
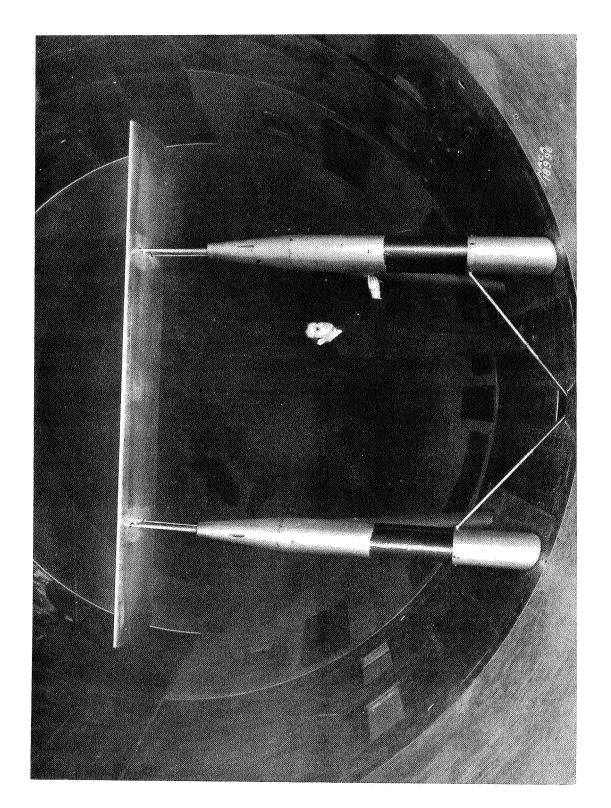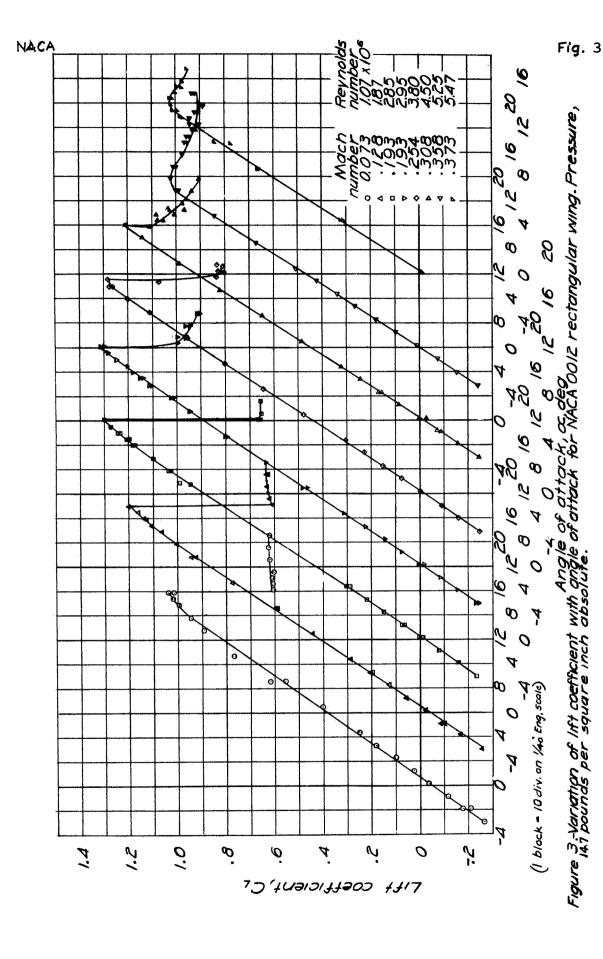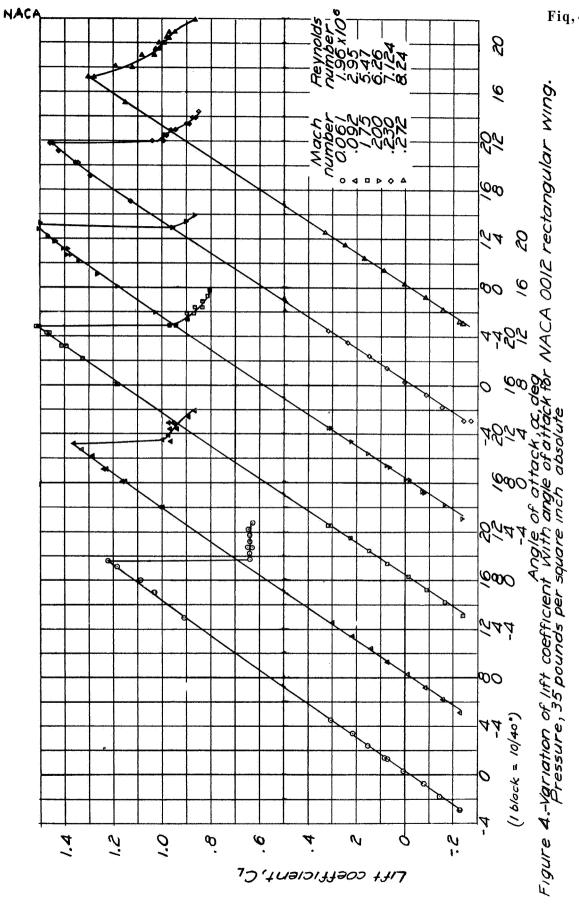   ibility on the Maximum Lift Coefficient. NACA
    A.C.R., Feb. 1943.

Fig. I

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OO12 Airfoil Ord.	
x (in.)	y (in.)
0	0
.300	.4546
.600	.6276
1.200	.8632
1.800	1.0090
2.400	1.1839
3.600	1.2628
4.800	1.3771
6.000	1.4258
7.200	1.4405
9.600	1.3927
12.000	1.2706
14.400	1.0951
16.800	.8794
19.200	.6296
21.600	.3475
22.800	.1897
24.000	.0912
L.E. Rad.	.3792

6.00

24.00

2.881

33.50

77.00

144.00

33.50

Model support points at 0.25c

All dimensions in inches

Figure I. - General dimensions of all-metal rectangular NACA OOI2 wing

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Figure 2.- Rectangular NACA 0012 airfoil model mounted on the normal supports in the NACA 19-foot pressure tunnel.

Figure 3.-Variation of lift coefficient with angle of attack for NACA 0012 rectangular wing. Pressure, 14.7 pounds per square inch absolute.

(1 block = 10 div. on 1/40 Eng. scale)

Fig. 3

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Figure 4.-Variation of lift coefficient with angle of attack for NACA 0012 rectangular wing.
Pressure, 35 pounds per square inch absolute

(1 block = 10/40")

Lift coefficient, C_L

Angle of attack, α, deg
Angle of attack

	Mach number	Reynolds number 1.96×10⁶
○	0.061	1.96
◁	.092	2.95
□	.175	5.47
▷	.200	6.26
◇	.230	7.124
△	.272	8.24
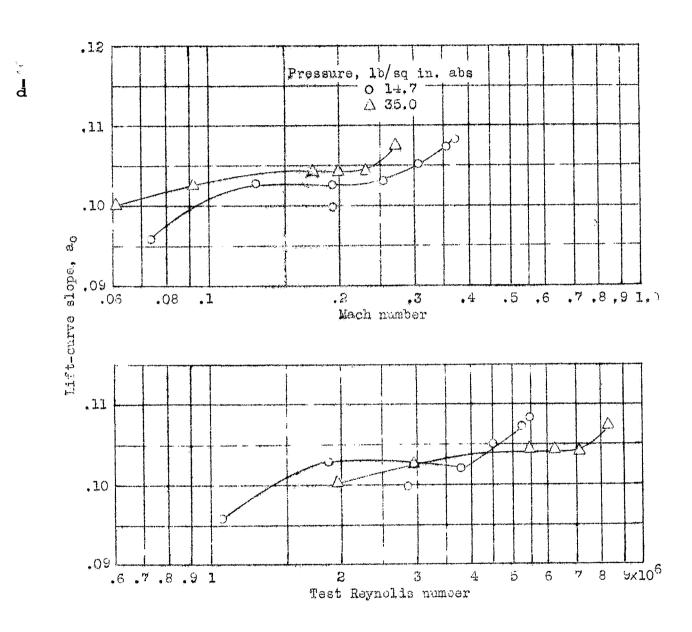
Figure 5.- Variation of lift-coefficient-curve slope with test Reynolds
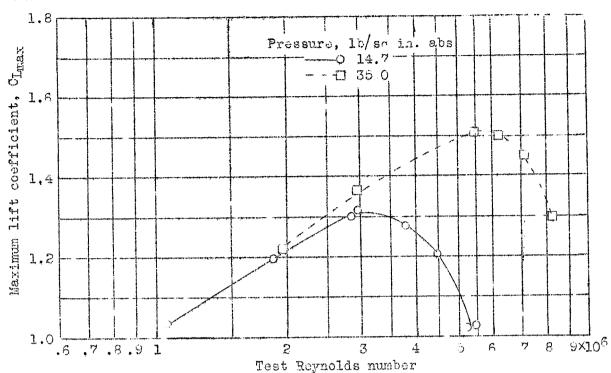number and Mach number for NACA 0012 rectangular wing.

Figure 6.- Variation of maximum lift coefficient with test Reynolds
number for NACA 0012 rectangular wing.
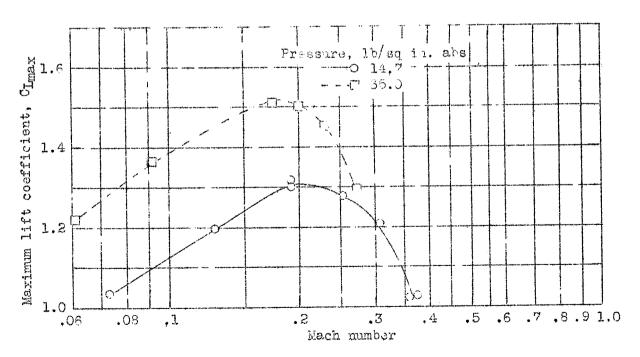

Figure 7.- Variation of maximum lift coefficient with Mach number
for NACA 0012 rectangular wing.